Appl. No : 10/678,109 Confirmation No.:
Applicants : John David Smith and Ming Yu
Filed : October 6, 2003
Title : MICROWAVE RESONATOR AND FILTER ASSEMBLY
TC./A.U. : 2817
Examiner : SEUNGSOOK HAM

Docket No. : 8989-006
Customer No. : 001059

Honorable Commissioner for Patents
P. O. Box 1450
Alexandria, Virginia 22313–1450

AMENDMENT

Sir:

In response to the Office Action of January 21, 2005, please amend the above-identified application as follows:

Amendments to the Claims are reflected in the listing of claims, which begins on page 2 of this paper.

Remarks/Arguments begin on page 5 of this paper.

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (Twice amended) A resonator assembly for operation within an electrical field at a desired frequency, said resonator assembly comprising:

(a) a resonator cavity having a top surface and a bottom surface;

(b) an elongated dielectric resonator having ~~with~~ a ~~substantially large~~ length to diameter ratio, said elongated ~~cylindrical~~ dielectric resonator being positioned within said resonator cavity;

(c) a first ~~and second~~ insulative support ~~supports~~ coupled between one ~~the~~ end~~s~~ of the ~~cylindrical~~ dielectric resonator and one of the top and bottom surfaces of the resonator cavity;

(d) ~~such~~ said length to diameter ratio of the elongated dielectric resonator being selected to be in the range of about 4.5 to 6.0 so that when ~~an~~ the electric field is applied to the resonator assembly, the half wave variation of the electric field ~~can~~ resonates at the desired frequency.

2. (Cancelled).

3. (Once amended) The resonator assembly of claim 1, wherein the dielectric resonator and the first insulative support ~~supports~~ are cylindrical.

4. (Once amended) The resonator assembly of claim 3, further comprising a second support, wherein said second support is coupled between the other end of the dielectric resonator and the other of the top and bottom surfaces of the resonator cavity and wherein the first and second insulative supports each have a diameter smaller than ~~substantially equal to~~ the diameter of the dielectric resonator.

5. (Once amended) A resonator filter for filtering an electromagnetic wave, said resonator filter comprising:

(a) a plurality of the resonator assemblies of claim 1 coupled to each other, adjacent pairs of said resonator cavities being separated from each other by a common cavity wall such that there are a plurality of common cavity walls between adjacent resonator cavities and such that each cavity wall has top and bottom edges;

(b) a first iris opening formed within a common cavity wall; and

(c) a second iris opening formed within a common cavity wall, said second iris opening having a position that is vertically offset from the position of the first iris opening.

6. (Original) The resonator filter of claim 5, wherein the resonator filter includes an input probe positioned on an input cavity wall for receiving the electromagnetic wave and an output probe positioned on an output cavity wall for providing the filtered electromagnetic wave, wherein said input probe is vertically offset from said output probe.

7. (Original) The resonator filter of claim 5, wherein the first iris opening is formed in the same common cavity wall as the second iris opening.

8. (Original) The resonator filter of claim 5, wherein the first iris opening is formed in a different common cavity wall than the second iris opening.

9. (Original) The resonator filter of claim 5, wherein the second iris opening is positioned at least one common cavity wall away from said first iris opening.

10. (Original) The resonator filter of claim 5, wherein all of the common cavity walls are of substantially the same dimension and share a common center line which is located halfway between the top and bottom edges of the cavity walls.

11. (Original) The resonator filter of claim 10, wherein the first iris opening is positioned above the center line and the second iris opening is positioned below the center line.

12. (Original) The resonator filter of claim 10, wherein said input probe is positioned below the center line of the input cavity wall and said output probe is positioned above the center line of the output cavity wall.

REMARKS/ARGUMENT

This letter is responsive to the Office Action mailed on January 21, 2005. The claims have been amended in response to the outstanding Office Action. No new matter has been added by the amendments.

The Applicant has cancelled claim 2. Accordingly, claims 1 and 3 to 12, as amended, are currently pending in the application.

Claims 1 to 4 rejected under 35 U.S.C. §103(a) in view of Bentivenga

The Examiner has rejected claims 1 to 4 under 35 U.S.C. §103(a) as being obvious in view of Bentivenga (U.S. Patent No. 5,262,742). As noted above, claim 2 has been cancelled.

The Examiner states that the Bentivenga reference discloses a resonator assembly (FIG. 9) that includes a resonator cavity, an elongated resonator 64 with a substantially large length to diameter ratio and insulated supports 66, each with a diameter substantially equal to the diameter of the resonator, coupled at the ends of the elongated resonator. When an electrical field is applied to the resonator assembly, the halfway variation of the electrical field resonates at a desired frequency (Bentivenga, column 4, lines 30 to 46). The Examiner has stated that while Bentivenga is silent as to whether the resonator is made of dielectric material, it is well known in the art to form a resonator with dielectric or conductive material and accordingly, it would be obvious to one of ordinary skill in the art to form the resonator with dielectric material.

In response, the Applicants have amended claim 1 to clarify the distinction between the presently claimed invention and the cited prior art reference. Independent claim 1, as amended, defines a resonator that uses an elongated dielectric resonator supported by an insulative support, where the length to diameter ratio of the elongated resonator is selected to be in the range of about 4.5 to 6.0 so that when the electric field is applied to the resonator assembly, the half wave variation of the electric field resonates at the desired frequency. Support for these amendments can be found in the disclosure at page 6 line 27 to page 7 line 6 and in FIGS. 2A to 2C, 5B to 5D, and 5B to 5D.

The Applicants submit that it would not be obvious to one of ordinary skill in the art in view of Bentivenga to provide a resonator that uses an elongated dielectric resonator where the length to diameter ratio of the elongated resonator is selected to be in the range of about 4.5 to 6.0 so that when the electric field is applied to the resonator assembly, the half wave variation of the electric field resonates at the desired frequency for the following reasons.

The Examiner is directed to column 4, lines 33 to 40 (and to FIG. 9) of the Bentivenga reference, which reads: "in this filter 60, a housing 62 similarly contains the same elements that are in the filter 30 in FIGS. 4 and 5, except that a series half-wave resonator rod 64 is used instead of a shunt half-wave resonator rod 36" (emphasis added).

The Applicants note that the series half-wave resonator rod 64 is supported on both ends by dielectric sleeves 66 (Bentivenga, column 4, lines 39 to 40). In essence, Bentivenga teaches that in order for the half-wave resonator rod 64 to function as a series half-wave resonator rod, the resonator rod must be electrically insulated from the cavity. In contrast, the shunt resonator rod 36 in FIG. 4 is directly coupled to the cavity to provide electrical contact between the resonator and the housing as is required for a shunt half-wave resonator. These co-existing structural requirements provide strong evidence that that the resonator rod 64 is conductive and that the resonator rod 64 is metal.

It is respectfully submitted that it is commonly accepted within the microwave field that for a particular resonator assembly, it is a complex and difficult endeavour to replace a metal resonator rod with a dielectric resonator rod equivalent. Metal and dielectric resonators possess substantially different electrical properties and as a result are not interchangeable dimension for dimension. As discussed in the background of the invention of the present application, metal dielectric resonators such as the metal combline resonator, when operational, produce an electrical field that exists outside the metal resonator body (Present disclosure, page 2, line 27-29).

In contrast, an operating dielectric resonator produces a certain amount of electrical field within the resonator. This difference produces a difference in the surface currents on the resonator rods as well as in terms of operational frequencies. Since some of the electrical field is contained within the dielectric resonator and not lost (i.e. as I^2R losses that would occur on the cavity walls) these electrical conditions result in a higher Q and improved filter performance. It is basic electrical differences such as these that prohibit replacement of a metal resonator rod with a dielectric rod having the same dimensions within a filter assembly.

As further evidence of this, the Applicants wish to provide the Examiner with the attached paper entitled "Dielectric Combline Resonator and Filters" authored by Chi Wang, et al in IEEE Transactions on Microwave Theory and Techniques Vol. 46, No. 12, December 1998. In this paper, the author indicates at page 2051, second column that "a novel type of coaxial resonator is introduced by replacing the inner conductor of the conventional combline resonator by a high dielectric rod... A rigourous mode-matching method is used for modeling of the dielectric combline resonator... in order to compute the resonant frequency, unloaded Q, and coupling coefficient".

This and other passages in the Wang paper clearly indicate that detailed and in-depth modeling and a strong design effort is necessary in order to arrive at an equivalent dielectric resonator rod. Accordingly, it is submitted that it would not be possible to simply replace the metal half-wave resonator rod 64 in the filter of Bentivenga with a dielectric resonator rod of the same dimensions. Rather, if that were done, the filter of Bentivenga would fail to operate.

Also generally speaking, replacing a metal resonator with a dielectric resonator having the same dimensions would result in an increase in the resonant frequency. Accordingly, in order to maintain the resonant frequency at the same value, it is necessary to replace a metal resonator rod with a dielectric resonator rod that has a longer length assuming a constant diameter. To quantitatively evidence this phenomena, the Applicants have conducted a simulation where it was determined that a metal resonator having length of 0.94 inches and a 0.11 inch diameter was determined to resonate at the same frequency as a dielectric resonator (with a dielectric constant of 45) having length of 1.34 inches and a 0.11 inch diameter. It is submitted that this simulation can be reproduced by anyone skilled in using commercially available simulation tools (e.g. HFSS™ manufactured by Ansoft Corporation of Pittsburgh, Pennsylvania, U.S.A.).

The Applicants note that Bentivenga does not explicitly disclose any specific dimensions for the half-wave resonator rod 64. However, the length to diameter ratio of the half-wave resonator rod 64 as represented in FIG. 9 of Bentivenga is roughly 9.0. In view of this, even if the dielectric equivalent could be provided, the length of the half-wave resonator rod 64 would have to be extended and would further exceed the 4.5 to 6.0 length to diameter ratio range as claimed in the present invention. Accordingly, it is submitted that Bentivenga teaches away from providing a resonator having a dielectric resonator where the length to diameter ratio of the elongated resonator is selected to be in the range of about 4.5 to 6.0 so that when the electric field is applied to the resonator assembly, the half wave variation of the electric field resonates at the desired frequency.

The Applicant respectfully submits that based on the teaching of Bentivenga and the prior art generally, it would not be obvious to provide a resonator that uses an elongated dielectric resonator where the length to diameter ratio of the elongated resonator is selected to be in the range of about 4.5 to 6.0 so that when the electric field is applied to the resonator assembly, the half wave variation of the electric field resonates at the desired frequency.

Further, claim 4, as amended, is directed to elongated resonator supported by first and second insulative supports, where the first and second insulative supports have a diameter that is smaller than the diameter of the dielectric resonator. The Applicant has found that by providing an insulative support having a diameter that is smaller than the elongated resonator diameter significantly improves the Q factor and the overall filter performance as well. This has been attributed to the fact that in the case of a dielectric resonator, the jutting edge of the elongated resonator generates a high concentration of electrical field. In contrast, the Examiner is directed to FIG. 9 of Bentivenga that visually illustrates that the diameter of the dielectric sleeve 66 is noteably larger than the diameter of the resonator 64.

The prior art "puck resonator" discussed in the present disclosure and disclosed in FIG. 1A of the present application uses a specific mode TE01δ that requires a large diameter to length ratio (e.g. 2 to 3) for optimal performance with respect to Q and spurious mode placement. As a result of this large diameter to length ratio, a smaller diameter support can be used without compromising the mechanical integrity of the device. However, the Applicants note that common resonator design practice as evidenced by Bentivenga teaches away from using a smaller diameter support for resonators having large length to diameter ratios for mechanical stability reasons.

The Applicant respectfully submits that in respect of claim 4, and based on the teaching of Bentivenga and the prior art generally, it would not be obvious to provide a resonator that uses an elongated dielectric resonator supported by two insulative supports, where each insulative support has a diameter that is smaller than the diameter of the dielectric and where the length to diameter ratio of the elongated resonator is selected to be in the range of about 4.5 to 6.0 so that when the electric field is applied to the resonator assembly, the half wave variation of the electric field resonates at the desired frequency.

Accordingly, the Applicant respectfully submits that the claimed invention is not shown or suggested by the Bentivenga reference. Withdrawal of the Examiner's rejection in respect of claims 1, 3 and 4 is respectfully requested.

Claims 5 and 7 to 11 rejected under 35 U.S.C. §103(a) in view of Estrada in combination of Bentivenga

The Examiner has rejected claims 5 and 7 to 11 under 35 U.S.C. §103(a) as being obvious in view of Estrada (U.S. Patent No. 5,812,036) and Bentivenga (U.S. Patent No. 5,262,742).

Specifically, the Examiner states that the Estrada reference discloses a resonator filter having a plurality of resonator assemblies coupled to each other where adjacent pairs of resonator cavities are separated by common walls (W1 and W3).

The Applicant submits that for the reasons discussed above in respect of claim 1, as amended, that the subject matter claims in dependent claims 5 and 7 to 11, as amended, is not shown or suggested by the Bentivenga or the Estrada references. Withdrawal of the Examiner's rejection in respect of claims 5 and 7 to 11 is respectfully requested.

Allowable Subject Matter

The Examiner has stated at page 4 of the Office Action that claims 6 and 12 would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

References Made of Record and Not Relied Upon

The Applicant has briefly reviewed the other references cited by the Examiner. The Applicant respectfully submits that these references do not recognize the problem solved by the present invention and do not describe or even suggest the present invention. The Applicant respectfully submits that they are not relevant to the patentability of the claims of the present invention.

In view of the foregoing, the Applicant respectfully submits that the application is now in condition for allowance. If the Examiner believes that a telephone interview would expedite allowance of the application, the Examiner is respectfully requested to contact the undersigned at (416) 364-7311.

Respectfully submitted,

SMITH ET AL.

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